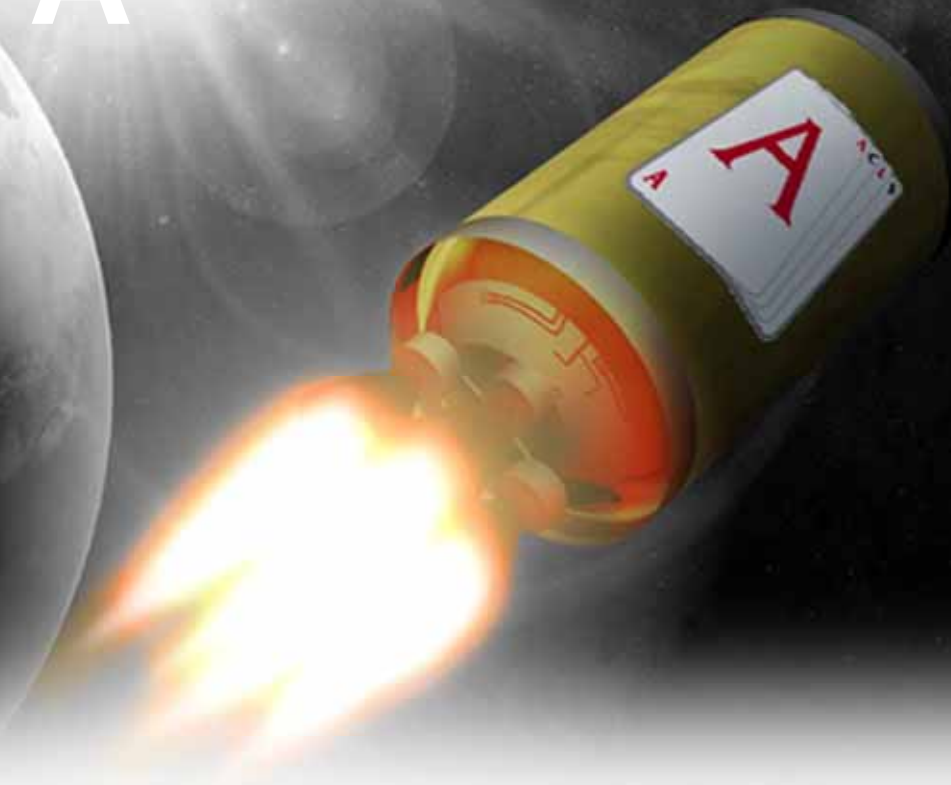


TRANSPORTATION ENABLING A ROBUST SPACE ECONOMY

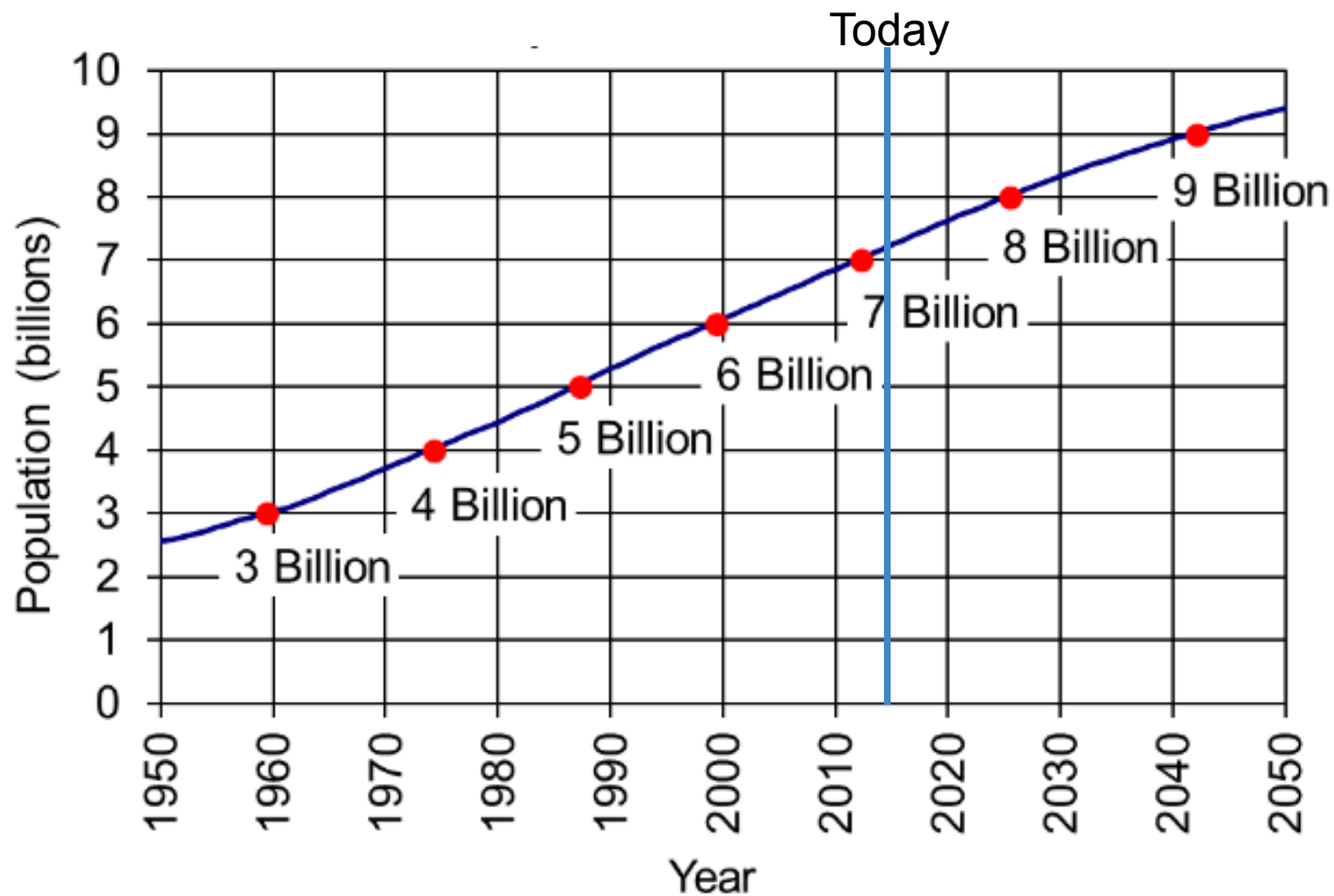
Bernard Kutter



12.7.17



CAN HUMANITY GROW AND THRIVE?



Source: U.S. Census Bureau, International Data Base, August 2017 Update.

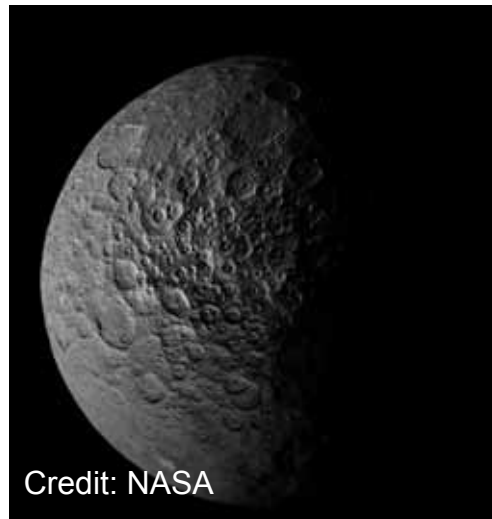
RESOURCE ALLOCATION

“The resources of our solar system are effectively infinite. The mineral wealth of just 50 asteroids would be enough to support a civilization of more than 10 trillion people.”

Art Dula, Trustee, Heinlein Prize

Ceres:

Dia=946 km, 9×10^{20} kg

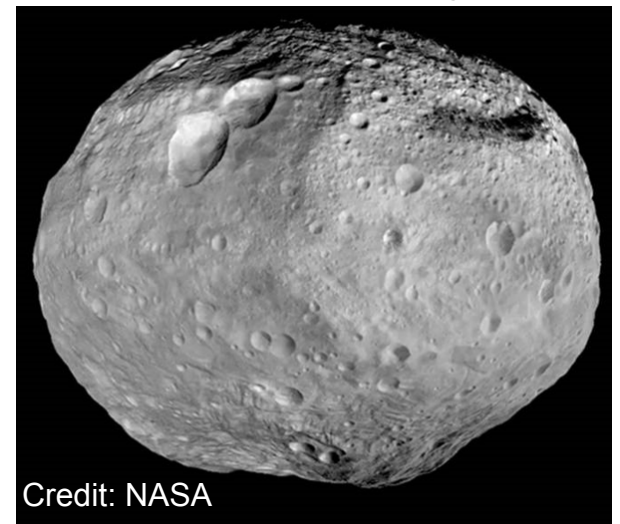


Credit: NASA

<https://www.nasa.gov/image-feature/fjp/pia21469/ceres-shadowed-craters-over-time>

Vesta:

Dia=525 km, 2.5×10^{20} kg



Credit: NASA

https://www.nasa.gov/mission_pages/dawn/multimedia/pia15678.html



GEO-BASED SPACE SOLAR POWER

DELIVERING 1,000x MORE ELECTRICITY THAN CONSUMED

LAUNCH HISTORY

ULA's Vision: Unleashing Mankind's Potential in Space
ULA is developing the enabling transportation system for a Self Sustaining Space Economy



CUSTOMERS

National Security Space



Intelligence,
Surveillance and
Reconnaissance

Global
Positioning
System (GPS)



Commercial Space



Commercial
Communication

Earth Imagery



Civil Space

Robotic Exploration and Science

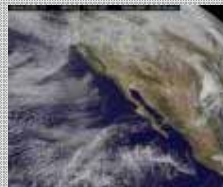


Mars Science
Laboratory

Pluto New
Horizons

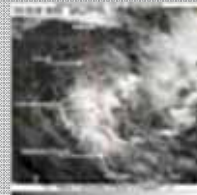


Increasing Our Knowledge of
the Earth and Its Climate



Geostationary
Operational
Environmental
Satellite (GOES)

Cloudsat



Human Launch



Cargo

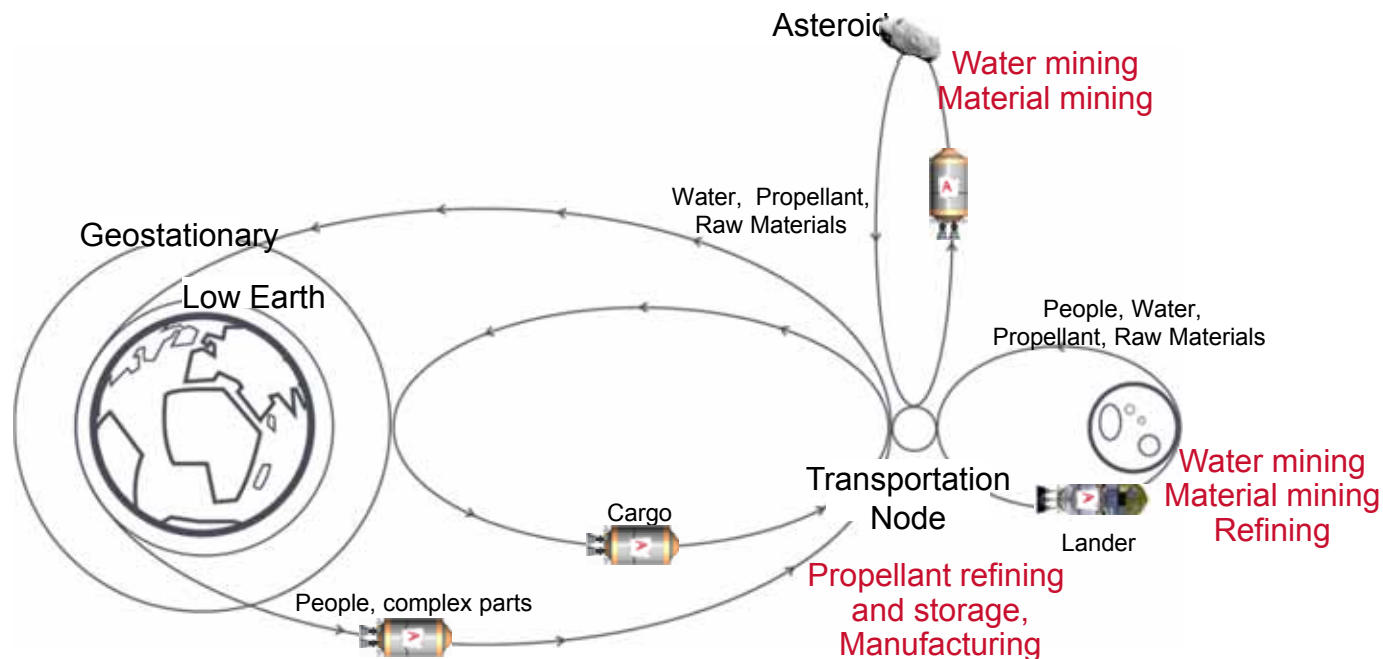


Crew

THE BROAD CISLUNAR ECONOSPHERE

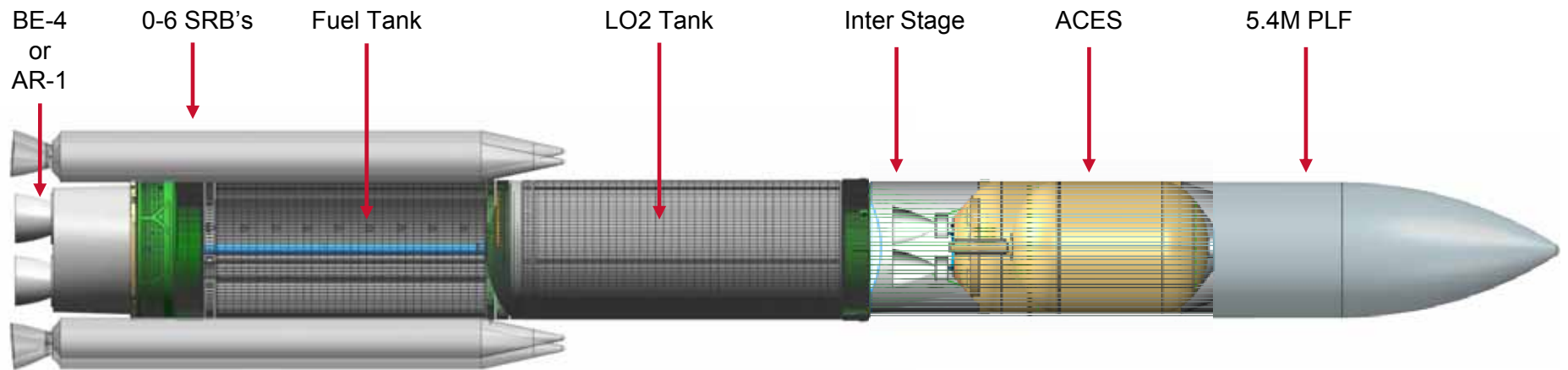
Huge Quantities of Precious Materials Reside on Asteroids & the Moon

- Billions of Tons of Water on the Moon
- Rocket Fuel and Life Support
- Power Generation
- New Materials Can Be Manufactured in Microgravity
- Potential Exists to Vastly Extend Economic Activity in Space



The CisLunar Economy is Enabled by a Practical Transportation System

VULCAN ACES

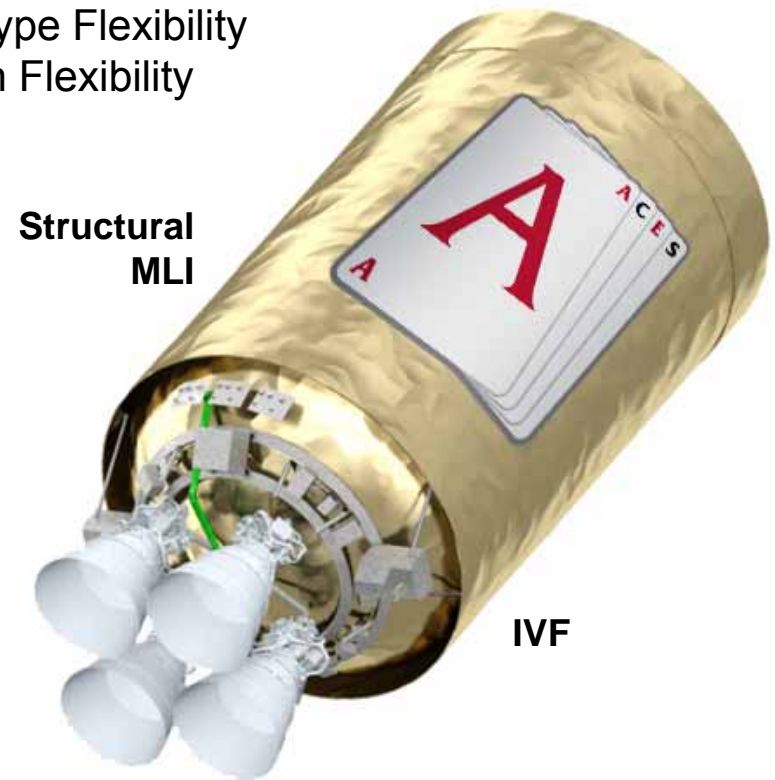


Booster Critical Design Review 4Q 2017

ACES – ADVANCED CRYOGENIC EVOLVED STAGE

New Mission Capability

- Weeks and Longer Duration
- Many Engine Burns
- Service Module Type Flexibility
- Increased Mission Flexibility



150 klb LO2/LH2
5.4m dia Tank
Stainless Steel
Monocoque
Common Bulkhead

ACES is the Key to Opening the CisLunar Highway
IVF and Cryo Storage Key Enabling Technologies

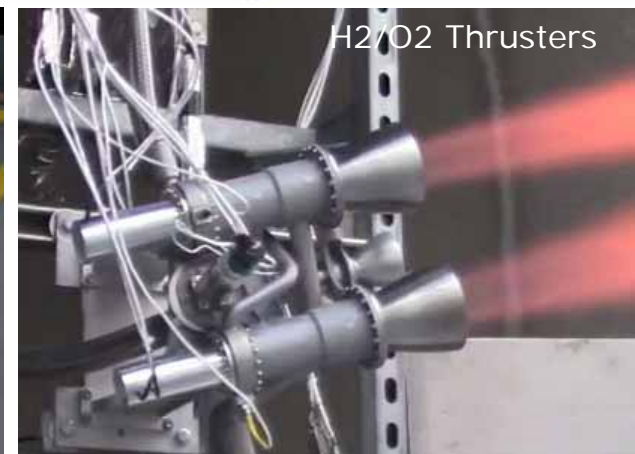
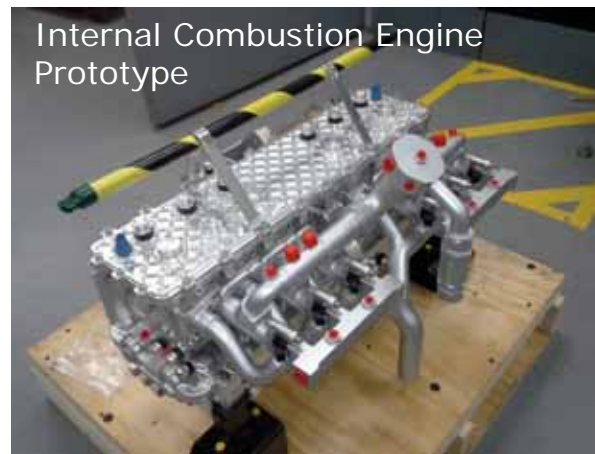
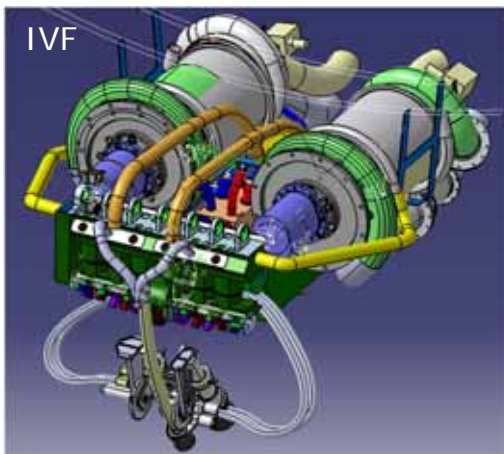
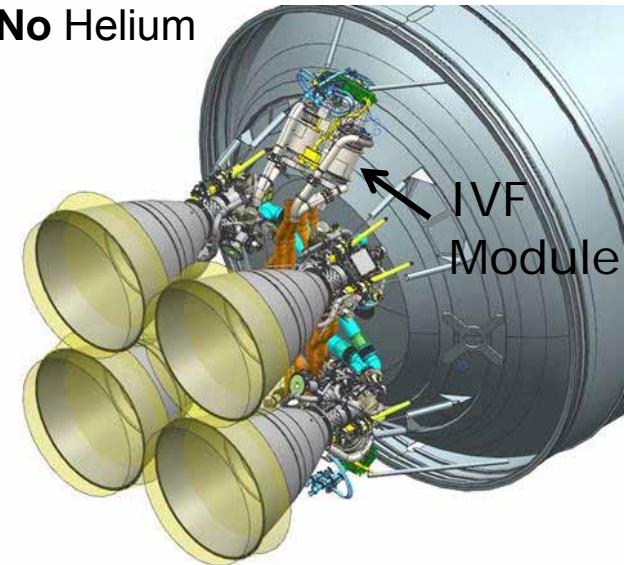
INTEGRATED VEHICLE FLUIDS ENABLES ACES

Powers Subsystems with “Waste” Propellants

- Power —> **No** Main Batteries
- Reaction control —> **No** Hydrazine
- Pressurization —> **No** Helium

Enables

- Service Module Flexibility
- **Ultra-Long Duration**
- On Orbit **Refueling**
- **Reusable**



CRYOTE 3 at NASA MSFC

ADVANCING CRYO FLUID MANAGEMENT

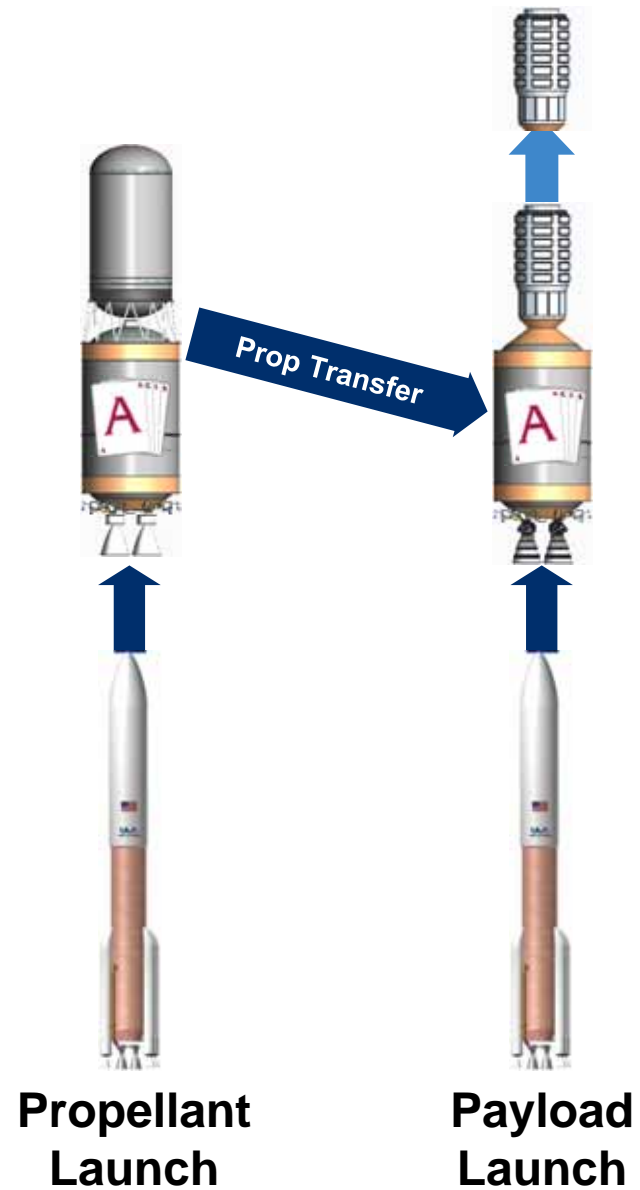


Initiate CRYOTE		CRYOTE 1 built		CRYOTE 1 LN2 Test		CRYOTE 3 Tank Delivery		CRYOTE 3 IVF Test	
2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	CRYOTE Light		CRYOTE Grande		CRYOTE No Vent Fill		CRYOTE 3 Cryo Test		

DISTRIBUTED LAUNCH

Vulcan	Earth Escape	GSO or Lunar Orbit	Lunar Surface
Single Launch	14 mT	10 mT	3.8 mT
Distributed Launch	30 mT	24 mT	12 mT

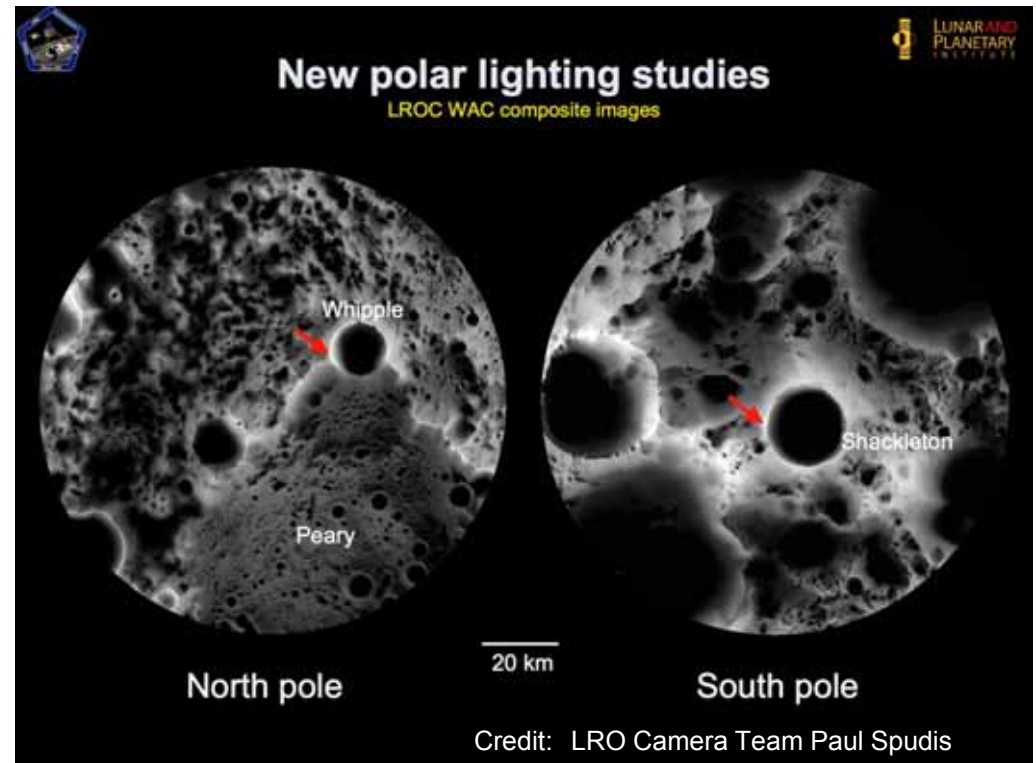
Initial Step to Upper Stage Reuse



LUNAR WATER

Water at Lunar Poles

- Cold Traps in Craters
- ~10mT per Pole
- Fuel, Water, Oxygen



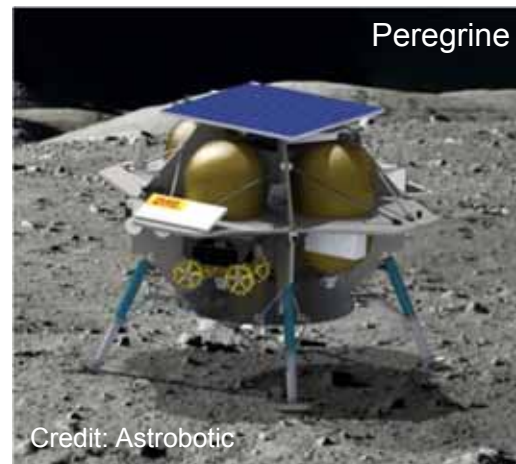
LUNAR WATER EXTRACTION

Power Tower on Crater Rim

- Beam Power to Crater Floor
- ## Sublimate ICE
- Collect and Liquefy
- ## Electrolyze Water
- Liquefy and Store
LH2 & LO2

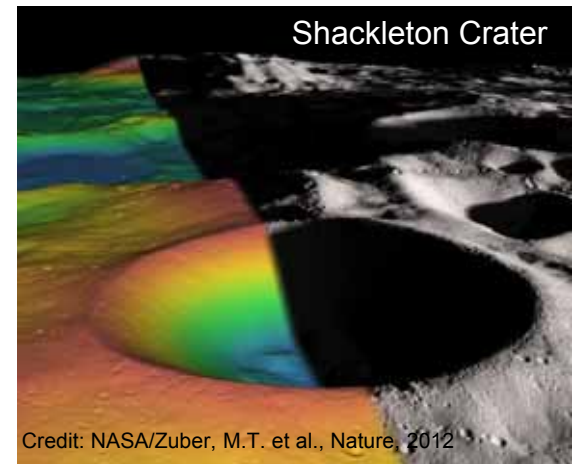


Resource Prospector



Peregrine

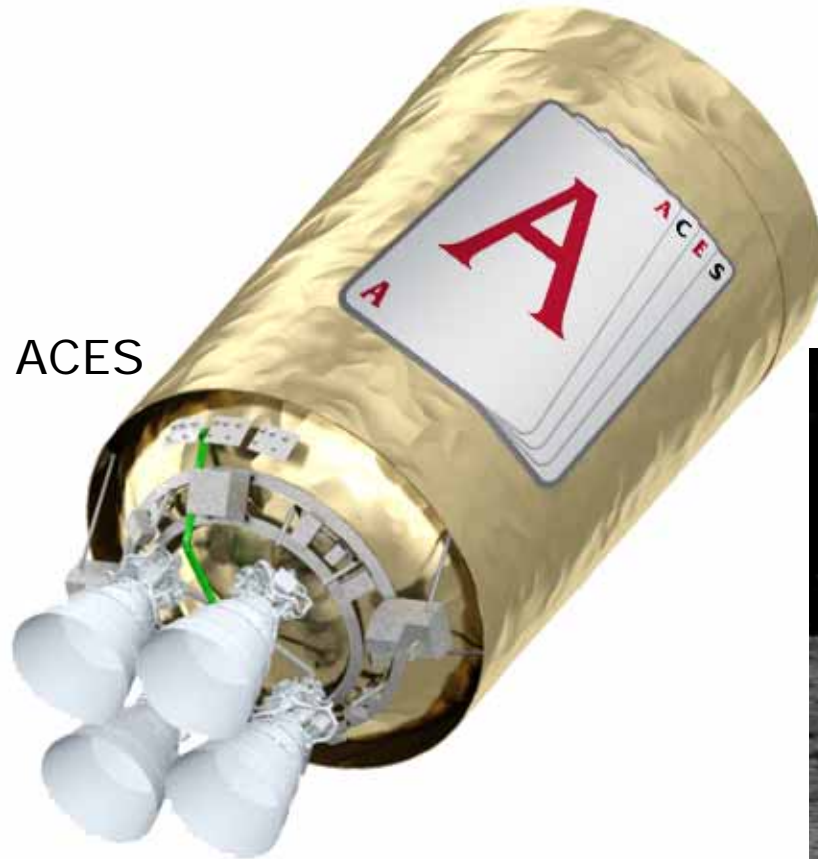
Credit: Astrobotic



Shackleton Crater

Credit: NASA/Zuber, M.T. et al., Nature, 2012

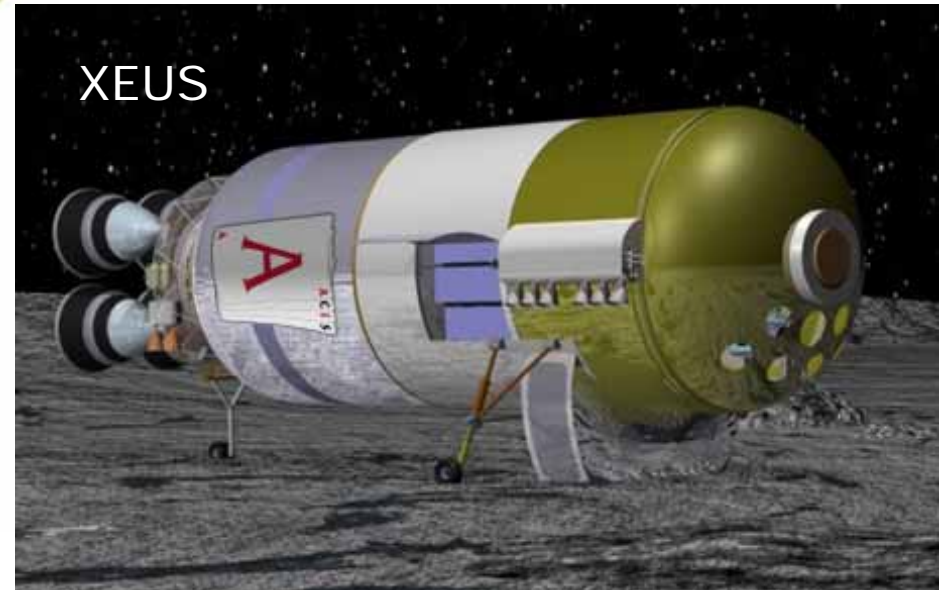
CISLUNAR TRANSPORTATION SYSTEM



ACES

Fueled with LO2 and LH2 propellant provided from:

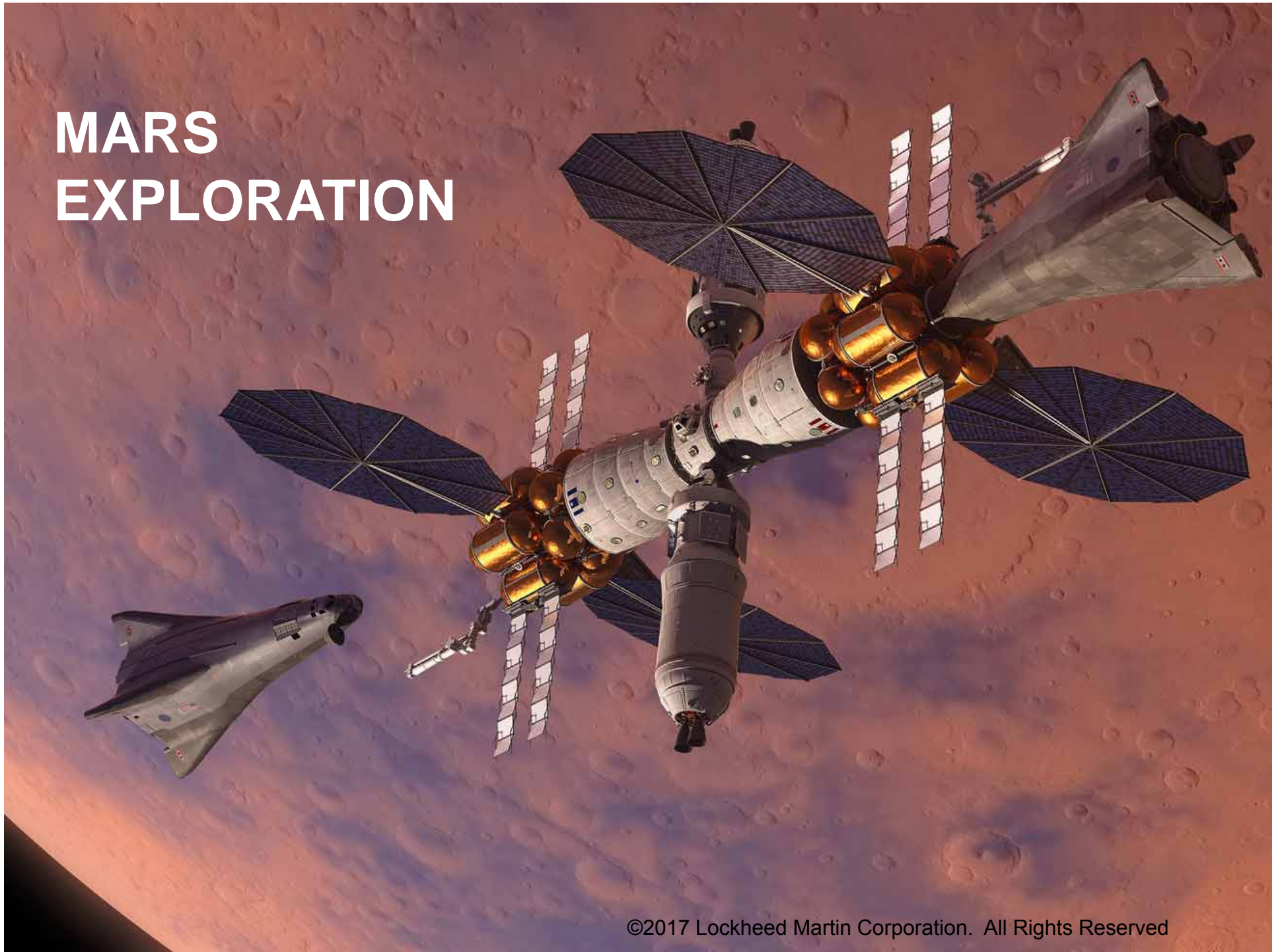
- Earth
- Moon
- Asteroids



XEUS

Reusable Transportation Avoids Earth's Deep Gravity Well

MARS EXPLORATION



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